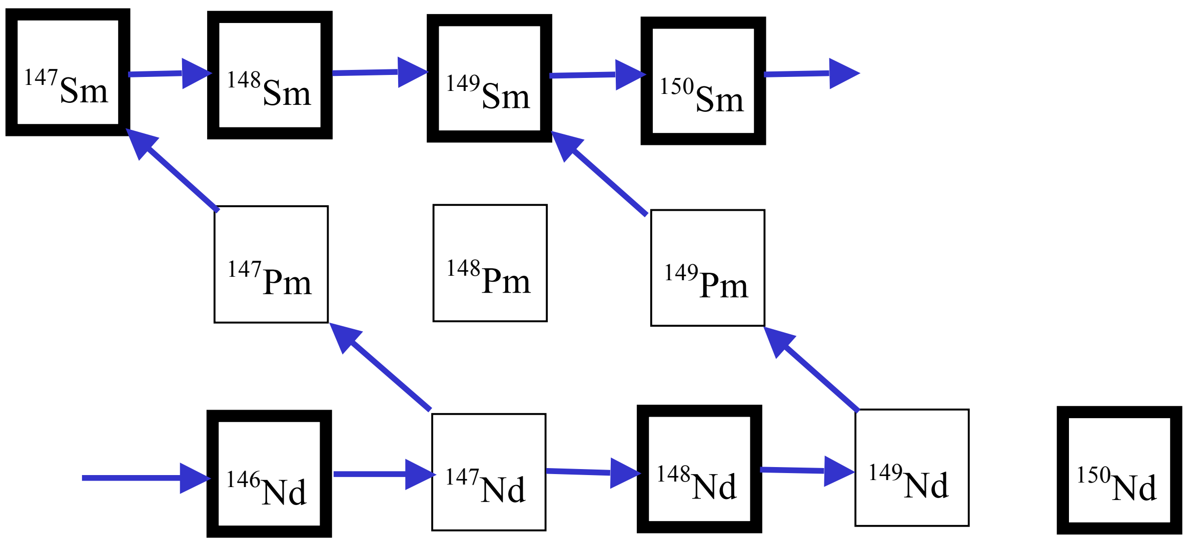
PHY983 - Nuclear Astrophysics - Spring 2013
Homework set 10
Due: Friday April 12
Key words: steady flow and s-process, r-process

1. The s-process branches at 147Nd because this isotope has a beta decay half life of 5.3 days (under stellar conditions, this is slightly modified compared to what you would find in a table of terrestrial rates), which is not too many orders of magnitude away from the neutron capture timescale. Below is a simplified scheme of the reaction flows in the Nd/Sm region during the s-process (stable isotopes are marked with thick lines)



As you can see 148Sm and 150Sm are s-only isotopes. The neutron capture rates for a stellar neutron spectrum corresponding to a temperature of kT=30 keV (typical for s-process) have been measured in the laboratory. The ratio of the 148Sm neutron capture rate to the 150Sm neutron capture rate could be determined particularly accurately and was found to be 0.596. This laboratory result can be used directly to determine the neutron density during the s-process (see Winters et al. ApJ300(1986)41 to see how this is really done – here we simplify the problem considerably).

a. [5 pts] Determine the fraction of the reaction flow that branched into the beta decay at 147Nd during the s-process that produced the solar system abundance distribution. You can use the steady flow approximation (which is locally a very good approximation) that tells you that the reaction flow is proportional to Yλ, where Y is the observed **s-process** abundance of the nuclide and λ is the rate of destruction per target nucleus. This means you can measure the (relative) flow that occurred during the s-process at any isotope provided you know Y and λ. Pick the suitable isotopes and work with ratios only.

b. [5 pts] Using the measured neutron capture rate for 147Nd at a temperature of kT=30 keV of 2e7 cm3/s/mole determine the neutron density during the s-process.

c. [5pts] Determine the relative r-process contribution to the solar abundance of ^{148}Nd using your result from 1a (use same temperature and reaclib database). Compare with the result from Arlandini et al. 1999 (*ApJ* **525** 886) http://iopscience.iop.org/0004-637X/525/2/886/ for their classical model and their stellar model (also give those two relative r-process contributions).

2. 2. [5 pts] The total mass fraction of all heavy (A>100) r-process nuclei in the solar system is about 1e-7. Given a supernova rate of 2.2e-2/yr/galaxy and a neutron star merger rate of 8e-6/yr/galaxy, calculate the total mass (in solar masses) of A>100 r-process nuclei that has to be ejected in either scenario per event to account for the observed r-process abundances in our Galaxy **assuming the respective scenario is the ONLY source of r-process nuclei**. Assume that the solar abundance distribution is typical for the whole Galaxy.